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THE IMPACT OF MINING AND GEOTECHNICAL FACTORS ON STRUCTURES LOCATED IN UPPER SILESIAN COAL BASIN – SELECTED EXAMPLES

VLIV HORNICKÝCH A GEOTECHNICKÝCH FAKTORŮ NA OBJEKTY V HORNOSLEZSKÉ UHELNÉ PÁNVI – VYBRANÉ PŘÍKLADY

Abstract

The scope of the paper is to present a number of mining and geotechnical factors influencing building structures located in Upper Silesian Coal Basin. The factors may contribute to damages, yet, it is not always possible to set apart their impact. Future mining works should take into consideration all mining and geotechnical conditions in a given region.

Abstrakt

Cílem příspěvku je ukázka řady hornických a geotechnických faktorů, které ovlivňují objekty v Hornoslezské uhelné pánvi. Tyto faktory mohou přispívat k poškození, avšak není vždy možné stanovit jednotlivé vlivy. Budoucí hornické práce by měly vzít do úvahy všechny hornické a geotechnice podmínky v dané oblasti.

Key words: mining and geotechnics factor, Upper Silesian Coal Basin, mining excavation

1 INTRODUCTION

In Upper Silesian Coal Basin intense hard coal mining extraction works have been conducted since the late 19th century. Mining works carried out in highly urbanized area have resulted in certain impacts involving hazards posed to many civil structures. The hazards are even more dangerous if they involve a wide range of different factors. In [1, 5] a wide spectrum of the mining impacts on the environment was discussed, including: continuous and discontinuous deformations and rock mass tremors. Continuous deformations always occur, irrespective of coal extraction conditions, yet they can be easily and exactly forecasted. On the other hand, discontinuous deformations , divided into surface and linear ones, occur at random. The surface deformations are usually an outcome of liquidating shallow voids in the rock mass due to further mining excavation, or to the incidences of tremors. The forecasting of the surface deformations usually comes down to determining their probability. The frequency of their occurrence is decreasing due to deeper underground mining works and the liquidation of shallow voids. However, discontinuous linear deformations are more threatening, because they are impossible to forecast. The incidence of many different factors often poses hazards to building structures, causing their damage [4]. While forecasting the state of deformations for planned mining extraction works, additional factors should also be taken into account, involving previously conducted mining extraction, as well as some specific geological and mining conditions. In certain circumstances other phenomena should also be considered, such as: land subsidence, reactivation of old gobs or ground steps, especially when the mining works are conducted in the vicinity of faults. In addition, there are other factors that may influence engineering structures, such as soil conditions or the location of the structures on, for example, a scarp. Examples of combined occurrence of various factors associated with mining works and evoking damages to buildings are discussed in the paper.

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2 EXAMPLES OF CONTINUOUS AND DISCONTINUOUS DEFORMATIONS AND ROCK MASS TREMOR HAZARDS

Several horizontal and diagonal cracks in the external and internal walls in a detached house were detected, as well as in the cellar floor. Furthermore, the house is tilted, which may be a result of not only mining works but also of ground movements of the escarpment on which it is situated. The most visible cracks and fissures are shown in the photographs below. It may be definitely assumed that the technical condition of the building is bad.

Fig.1: Cracks in the ground floor walls

Fig.2: Cracks in the walls at the door opening

2.1 Rock mass structure

In the vicinity of the examined house the Quaternary and Triassic formations may be found only at 0.6 m of the soil and clay layers. Below, there are layers of limestone and dolomite with the thickness of about 5.2 m, sandstone and slate with the thickness of about 11 meters belonging, as far as the stratigraphic manner, to the Triassic formations and 16 m layer of Stefanian sandstone. Below there are slate and sandstone layers belonging to “łaziskie” coal layers.

2.2 Completed mining excavation

Mining works had been conducted before the house was erected and also in the successive years. Before 1950 no direct impacts were recorded, yet, due to the location of the mine headings at shallow depth, a short characteristics of the excavation should be presented:

- Seam 207 located below the house was worked in 1873 with caving at the height of 4.2 m and depth of about 42 m.
- Seam 208 worked in 1892r with caving at the height of 1.8 m and the depth of about 115 m.
- Seam 209 worked in 1980 with caving at the height of 4.8 m and the depth of about 150 m.
- Seam 210 worked in 1941 with caving at the height of 1.6 m and the depth of about 180 m.

The successive mining extraction works were carried out after the erection of the house. Basic information concerning the effected mining works is presented in Table 1 below.

Table 1Basic data on the mining works conducted after the erection of the house

Coal seam	Panel/	Begin of extr.	End of extr.	Thickness of seam [m]	Angle inclin. [deg]	Depth [m]	Distance [km]	a
210	1	01-04-1964	31-12-1964	1.60	8	180	0.10	0.25
210	2	01-01-1965	30-06-1965	1.80	8	195	0.14	0.25
210	3	01-09-1964	15-04-1965	1.80	8	195	0.16	0.25
214	11	01-04-1976	15-11-1976	1.90	8	390	0.05	0.25
214	12	01-06-1969	30-03-1971	1.80	8	360	0.08	0.25
301	13	01-06-1968	01-11-1968	2.30	8	470	0.20	0.25
301	14	15-10-1968	15-08-1969	2.40	8	445	0.16	0.25
301	4	15-10-1965	01-01-1967	2.10	8	465	0.00	0.25
301	5	15-10-1965	30-06-1967	2.10	8	465	0.04	0.25
301	6	15-01-1967	01-08-1967	2.40	8	430	0.13	0.25
301	7	01-02-1967	01-08-1967	2.40	8	425	0.18	0.25
302	10	01-04-1970	30-08-1970	1.25	8	480	0.14	0.80
302	8	01-01-1970	30-06-1970	1.30	8	470	0.00	0.80
302	9	15-06-1971	30-09-1971	1.40	8	450	0.08	0.80

The calculations were made on the grounds of W.Budryk – S.Knothe theory [2] and DEFK software [6]. The software makes it possible to calculate the deformation indices evoked by the extraction of any number of n–angle polygons. The following parameter values were assumed for the calculations:

- **a = 0.80** – coal extraction with roof caving
- **a = 0.25** –extraction coefficient with hydraulic fill
- **tgβ = 2** general mining impact tangent
- **B = 0.32** proportionality coefficient appearing in Awierszyn's compound and determining the values of the horizontal displacements and deformations.

The location of the coal mining seams in relation to the examined damaged house was shown in Fig.1.

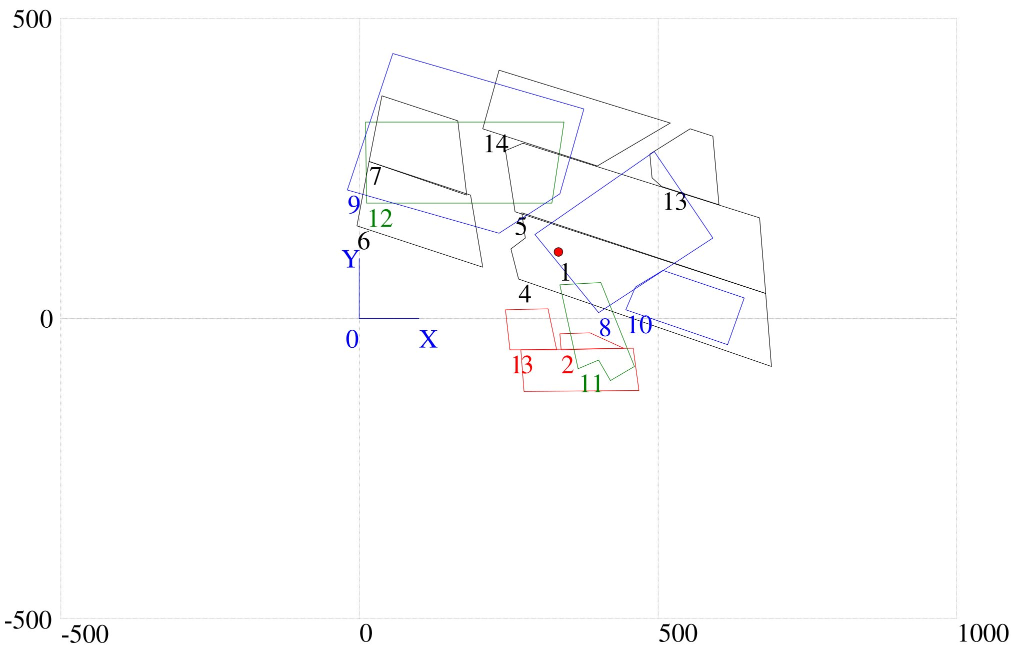

Fig.3: The location of the excavated sites as related to the examined house.

The numbers of the sites shown in the Figure correspond to the numbers stipulated in Table 1. The house is marked by the red circle.

Table 2 The calculation results

Seam	Panel	w	Tmax	Umax	Emax	Kmax
mm	mm/m	mm	mm/m	1/km		
210	1	-0.1	0.01	0.3	0.03	-0.001
210	2	0.0	0.00	0.0	0.00	0.000
210	3	0.0	0.00	0.0	0.00	0.000
214	11	-21.7	0.46	28.6	0.42	-0.007
214	12	-40.1	0.92	52.7	0.86	-0.015
301	13	-7.2	0.17	12.6	0.24	-0.003
301	14	-36.5	0.74	52.3	0.76	-0.011
301	4	-156.0	1.08	80.0	-0.97	0.013
301	5	-187.5	1.15	85.3	-1.01	0.014
301	6	-10.3	0.26	18.1	0.38	-0.006
301	7	-2.1	0.07	4.5	0.13	-0.002
302	10	-18.8	0.40	30.5	0.51	-0.007
302	8	-384.1	2.67	200.0	-2.33	0.031
302	9	-203.3	3.06	219.9	1.93	-0.027
suma		-1067.6	2.68	195.0	-4.25	0.058

The effected mining excavation has caused the following deformations at the site:

- subsidence w = -1.068 m
- maximal tilt Tmax = 2.68 mm/m
- maximal horizontal displacement Umax 0.195 m
- maximal vertical displacement Emax = -4.25 mm/m
- maximal vertical curvature Kmax = 0.058 1/km

As seen in the above Table, the examined house was subjected to the impacts of land subsidence of the values about 1.07 m, the tilt of the second category and the third category of horizontal displacement. The values of the deformation indices could have been higher in view of the reactivation of old shallow gobs.

2.3 Discontinuous deformations

In 2006 at the distance of about 50 m from the house there occurred land subsidence with the dimensions of 3.5m x 5.0 m and the depth of 3.0 m. In February 2006 a specialised company conducted geo-physical tests by means of the electro-resistance method, the measurements were taken at 5 m x 5 m in the area of 50 m x 110 m. Low and high-values of resistance anomalies were detected. The low resistance value anomalies involved the infiltration of water or sewage from the rock mass to unsealed pipelines. The high resistance value anomalies point to the presence of cracks and crevices, and, in the extreme points, to the presence of voids. The tests were carried out by means of two measurement systems at the depth range of about 20 to 30 m. It should be emphasised that the above mentioned subsidence emerged at the range of minimal anomaly range of about 10 izo-oms.

In the next phase ground soil treatment works were conducted. 30.55 m3 to 457.71 m3 of fill was put into 10 drilled holes. In the course of the conducted works the previously filled subsidence trough was activated. The voids in two holes were detected: (at the depth of 25-25.5 m and 28 – 30 m, and the height up to 0.5 m). Numerous zones of cracks were detected at the depths of: 30 m, 31 m and 32 m.

A volume of 189.89 m3 to 1041.06m3 of fill was placed in further 8 holes. The works were conducted until the capacity (absorptive power) of the holes was used up. Control geo-physical tests proved that the rock mass was sealed. Successive tests (conducted by means of the gravimetrical method proved the occurrence of anomalies in three areas, which may prove the presence of the voids in the rock mass.

Excerpts from the map of the shallowest seam 207 with the marked building and the subsidence are shown in Fig.2.

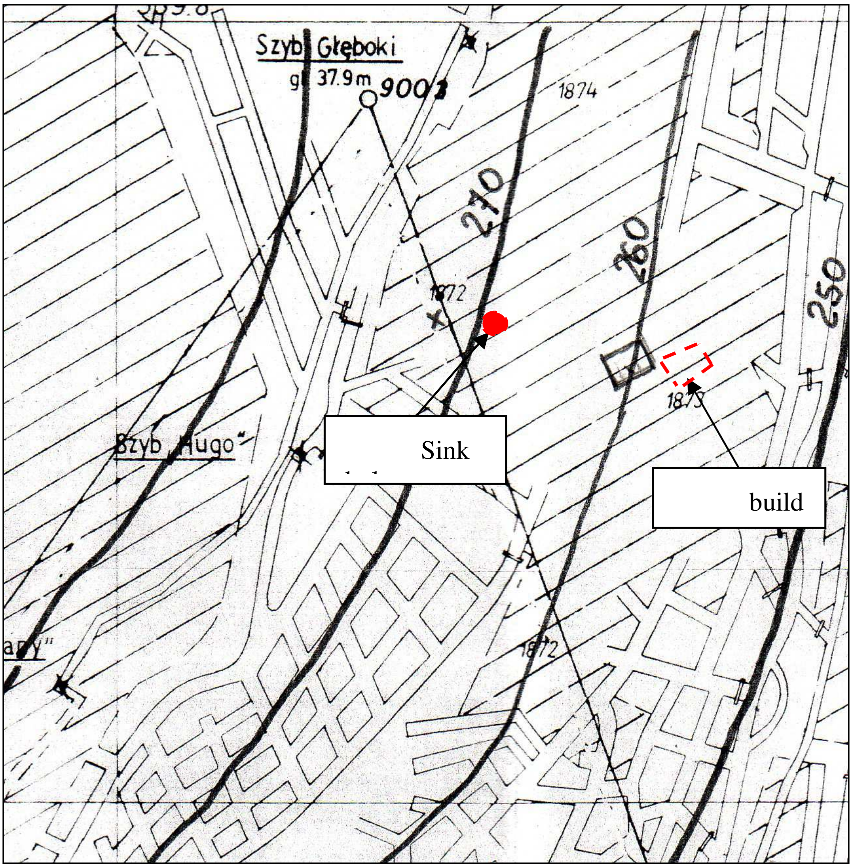

Fig. 4: The map of coal seam 207

2.4 The impact of the tremors on the building and self-formation of the voids in the rock mass

The values of the acceleration of the tremors were calculated on the bases G. Mutke's formula [3]:

$$a = [1.33 \cdot 10^{-3} \cdot (\log E)^{2.66} - 0.089] \cdot [1.53 \cdot R^{0.155} \cdot \exp(-0.065 \cdot R) + 0.014]$$

where :

a – acceleration of the tremors, m/s2

$$R = \sqrt{D^2 + 0.5^2}$$

d – epicentre distance, km

E – energy of the tremor J

The highest values of the acceleration of the tremors at the assumed values of coefficient **k = 1.2 - a = 27 mm/s2,** and, assuming that: **k = 2 - a = 44 mm/s2 .**

In view of MSK-64 scale outline the derived values of the accelerations are insignificant and could not have contributed to the damage of the building, and, most probably, on the reactivation of the voids.

3 EXAMPLE OF THE OCCURRENCE OF DISCONTINUOS LINEAR DEFROMATIONS

3.1 The structure of the rock mass

The rock mass in the investigated area is made up from the Triassic and Quaternary layers with the thickness of about 100m. The overlay contains carbon.

3.2 Tectonic disturbance

There is a tectonically disturbed zone in the vicinity of the faults- from the north-western to the south eastern direction with the height of the faults not exceeding 20 m.

3.3 Completed mining works

In the area of the faults the following mining extraction works were conducted (Fig.3) by longwall and roof caving method:

- 352 in 1980-83 at the height of 2.2m-2.7m and the average depth of 600m.
- 357 in 1984-89 at the height of 2.0-2.25m and the average depth of 650m.
- 358/1 in 1993-94 at the height of 1.7m and the average depth of 650m.
- 359 in 1990-96 at the height of 1.7m and the average depth of 600m-750m.
- 361 in 1997 at the height of 2.3m and the average depth of 650m.
- 405/1 in 1992 at the height of .2m and the average depth of 830m.

The deformations occurring in the south-eastern part of the discussed area involved the fault zone and the edges of the extraction zones of seams: 352, 357, 359. The deformations occurring in the central part of the area stem from the divergence of the mining extraction impacts evoked in seams: 352, 357, 358/1, 359, 361.

It is interesting to point out that the deformations appeared at the time where mining extraction was no longer performed.

In the discussed examples the reasons for the occurrence of the deformations have been associated with the convergence of the mining extraction carried out in the mentioned seams and the existence of the fault in the south-eastern part of the area. Surprisingly, it should be emphasised that at the time of the occurrence of the deformations, no mining works were conducted in the discussed area.

4 CONCLUSIONS

There has been intensive underground hard coal extraction led since XIX century in the Upper Silesia Basin. Firstly, shallow coal seams were mined out, sometimes at the depth of several meters. Very often extracted workings in these times were not properly liquidated. This situation was sometimes the cause of discontinuous deformations arising, mainly in the shape of sinkholes. Later extraction went deeper, as the shallow resources of hardcoal were exhausted. Nowadays we have extraction led below 1000m in some coal mines. Due to this fact, in present days, the hazard of sinkholes occurring is less important then in the past. But deep extraction may influence (may “reactivate”) old shallow not filled workings and this can be the cause of sinkholes arising. This reactivation can also have another impact on the surface – one may observe greater values of deformation indices caused by present extraction. Another problem is connected with second type of discontinuous deformation – “linear” – in the shape of cracks and ground steps. Their occurrence is connected with extraction led in several coal seams toward the same border (e.g. the border of safety pillar).

Fig.5: Location of the mining excavation works in relation to the geological faults

Continuous deformations as well as discontinuous ones and tremors induced by present underground extraction are very often the main cause of damage to building constructions in the Upper Silesia Basin. Apart from them, there are several other factors, mainly geotechnical, e.g.: changes in ground layer properties. One should keep in mind the importance of these factors in designing of underground extraction in urbanized areas. In the Upper Silesia Basin the costs of restoration of buildings damaged due to mining activity is approximately 3% of extraction costs.

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